Experiences in applying augmented reality techniques to adaptive, continuous guided tours.

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Abstract

This paper presents initial results and experiences based on a novel concept of augmented reality guided tours in the framework of the EU-IST LIFEPLUS research project. The acronym stands for "Innovative revival of life in ancient frescoes and creation of immersive narrative spaces featuring real scenes with behavioured virtual fauna and flora". The project explores and implements a new generation mobile augmented reality guide resembling a "time travel machine", which immerses the visitor not only into a reconstruction of monuments and events but also into the everyday life of past civilizations. It is currently under trial in the ancient city of Pompeii, Italy.

Keywords: augmented reality; mobile; personalized; interactive, location-sensitive.

1 Introduction

The cultural heritage sector has always been perceived as an "avaton" (prohibited zone) for technology and novel approaches and methodologies. This attitude has been supported for a number of years by archaeologists, historians, museologists and other scientists active in the field. Although modern techniques and hi-tech systems have slowly been adopted in conservation and research, there has always been scepticism and reluctance in adopting them in the presentation of ancient or more recent treasures to the general public. For this reason the "traditional" display windows and the paper guidebooks and plans have been the main tools used in promoting cultural heritage and helping people to explore it.

The techniques are still widely used in museums and archaeological sites and despite the help they offer visitors they limit the visibility of the very objects they promote. For instance, consider the small signs posted in display windows. They briefly describe the object in display in usually one to three languages. However, this description fails to address the particular visitor's interests (e.g. an adult is interested in more detail compared to a teenager who simply wants to catch a glimpse of something unusual and eye-catching), or even his mother language if he comes from a foreign country. Similarly, the visitor may spend more time reading his guidebook than observing the exhibits or surroundings and therefore miss the experience he could otherwise live.

These and other similar limitations have been addressed by scientists and cultural heritage managers and a new trend has slowly been developed towards the use of digital technologies for guiding and informing the visitor. The first such approaches consisted of audio-CD guides and were followed by CD-ROM presentations, info-kiosks and virtual reality (Pletinckx 2001, http://www.ammi.org/site/site.asp [2001]).

More recent digital guidance systems are build on the concept of mixed reality where views of the real environment are mixed with computer graphics and presented on a computer's screen either as photographs or panoramas and videos (Hutchins 2003, Scagliarini 2001, http://www.museum.molndal.se/indexn.asp [2003], http://www.eloqu.com/webpage_german/web_eloqu/projekte/sim/BerlinerMauer/DEFAULT.HTM [2003]).

The latest developments in such systems use augmented reality (AR), a technique where the user views his surroundings through a special pair of glasses and binoculars. These devices enable the display of computer models (static or animated) in appropriate positions, so as to appear like they really exist in front of him (Feiner 1997, Holweg 2002, Parent 2000, Scagliarini 2001, Vlahakis 2002, Yura 1996). This illusion is made possible with special image processing techniques, sensing devices and powerful computers. The need for such systems stems from the fact that visitors need continuous and personalized guidance, and additional immersive information presented in an intuitive and interactive nature so as to enhance the real environment and exhibits. The next section gives a brief introduction of the most common AR systems.

2 AR Technology Background

AR systems consist of four main components: a processing unit, a tracking system, a visualization device, and an interaction module.

The processing unit is typically implemented in the form of a mobile computer, a laptop, or a notebook. It has to have the following characteristics:

- High processing power to handle real time 3D graphics and animations, supported by a fast 3D graphics card
- Compact size to allow for easy carrying during the user's visit in an indoor or outdoor site.
- Light weight to allow carrying by all users, including females and children, for long times; typically 1 hour or more.

The tracking system is an essential component responsible for understanding the user's intentions and allowing the computer to automatically provide him with information. It consists of a GPS position detector, a digital compass for orientation detection, and an optical tracking system. The last one uses the video signal of a camera aligned with the user's field-of-view and feeds it to the processing unit where real-time video tracking is used to refine the initial position and orientation estimations from the other sensors and calculate the exact position where the graphics should be added on top of the natural view.

The aligned graphics are then fed to the visualization device carried by the user. It may be in the form of a reconstruction model of a monument, a text tag, or an animation where avatar characters interact in the real surroundings of the user. These models have transparent background so as to leave the natural view visible. The visualization devices usually come in two forms:

- A head-mounted display (HMD) resembling a lightweight cask or helmet upon which special AR glasses are attached together with a web camera, compass and small earphones.
- A pair of AR binoculars integrated with a web camera and separate earphones.

Both devices create an illusion where the user is surrounded by artificial (virtual) objects and characters as if they exist in front of him.

The final component of an AR system, namely the interaction module, provides the necessary means for the user to communicate his intentions to the computer and request additional audiovisual information. This way he can indicate which object he is interested in, he can interrupt an audio or visual presentation, or simply view a plan of the site or museum he is visiting.

The pioneering application of mobile augmented reality outside confined laboratory spaces is the MARS (Mobile Augmented Reality System) project (Feiner, 1997). This is a mobile AR platform used for guiding students in the campus of Columbia University. A more recent project, ARCHEOGUIDE (Augmented Reality-based Cultural HEritage On-site GUIDE) (Vlahakis 2002) has been demonstrated at the archaeological site of Olympia in Greece for the reconstruction of ruined monuments and the revival of Olympic Games sports disciplines in the stadium were they once took place. Both systems use the technologies briefly mentioned above.
Other applications include the Timescope system used at Ename in Belgium for the reconstruction of an ancient Cathedral (Pletinckx 2001). However this is a fixed system in the form of an AR info-kiosk. Similarly, Visorama (Parente 2000) in Brazil is an AR telescope used for the presentation of the tourist attractions of Rio de Janeiro.

Going back to the mobile guides, other outstanding examples are the Tokyo University Digital Museum (Yura 1996) where AR information on the exhibits is given, and GEIST in Germany for AR tours of historical city centres (Holweg 2002).

LIFEPLUS uses technological know-how from the ARCHEOGUIDE project. ARCHOEGUIDE employs mobile devices for delivering AR tours but it does so only at pre-defined viewpoints and only for the presentation of simple 2D video animations and building reconstructions. LIFEPLUS goes one step further with the continuous delivery of AR tours at any point in the site including both indoor and outdoor areas. In addition, it introduces high quality, real-time 3D graphics and avatar animations, dynamic personalization, and continuous avatar guiding.

From a user's point of view, AR guides should be easy to use, require no previous experience with computers, provide intuitive interaction, content personalization, and photo-realistic 3D graphics and animations. These features are all addressed by LIFEPLUS and have been implemented in the initial prototype. Furthermore, users are interested in lightweight and compact devices, capable to withstand the shock of an accidental fall, and with autonomies of more that one hour. These features are under investigation in LIFEPLUS and they are expected to be added to the next system prototype.

3 The LIFEPLUS System

The proposed system consists of two major subsystems, namely the augmented reality guide for site touring and the component for the simulation of ancient life at pre-defined points of interest. This paper focuses on the presentation of the augmented reality guide. The work carried out here reuses knowledge and experiences from the ARCHEOGUIDE project but introduces a set of significant modifications both from a technical and a content point of view. The newly developed platform allows for continuous narration and guidance combined with presentation of visual material along the path of the visitor.

LIFEPLUS research aims at producing a portable electronic tourist guide for personalized audio-visual tours of archaeological sites. The system consists of 3 main modules: a central server, mobile devices and wireless communications infrastructure. The server manages a multimedia database of cultural and tourist information and services mobile users' requests for multimedia content and control information. This traffic is handled by a radio network, which services a number of concurrent users.

The mobile devices are built on off-the-shelf notebook computers with powerful 3D graphics hardware. They integrate hybrid user-tracking modules combining GPS receivers, digital compasses and cameras for real-time video processing, offering synchronized, location and orientation-based audio-visual content. This hardware guarantees the delivery of realistic augmented reality presentations where the ruined buildings of the ancient site are reconstructed with high-quality computer-generated models. The system seamlessly blends the real with virtual worlds while at the same time offering synchronized audio narration in a selection of languages.

The presentation is made user-friendlier with the inclusion of an avatar (virtual 3D human character) guide, which provides navigation, historical and other information (illustrate in Fig. 1). The multimedia content is tailored to the user's profile, available for the visit and his reactions. It is provided on a position and orientation-sensitive basis, eliminating user interaction. Nevertheless, multi-modal interaction techniques are supported and the user can at any point intervene to alter the flow of information or gain access to additional data. Examples include digital versions of site maps and tour paths, and access to images and manipulation of 3D models of digitized museum artifacts.

The other side of the mobile guide implements an augmented presentation of ancient life in its original surroundings. In other words, the touring user can view everyday life in the ancient times in the very spot it used to happen. This way lifeless ruins and artifacts are filled with avatars and their use and significance is explained in a highly intuitive and realistic way. This scenario follows information and depictions from ancient frescoes and makes use of complex 3D animations of photo-realistic quality with natural hair and clothes modeling.

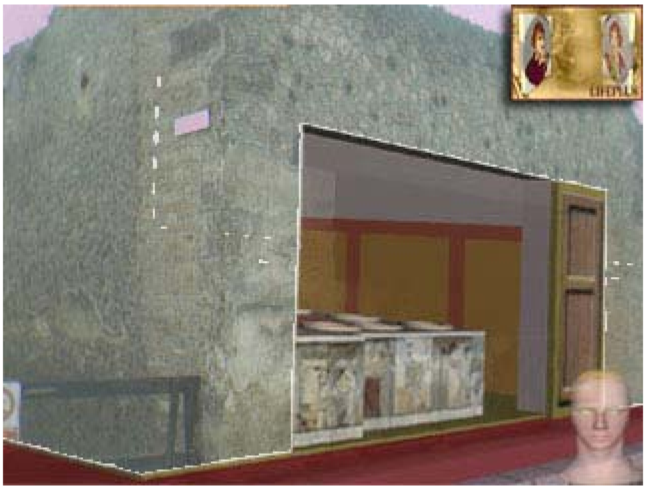

Fig. 1: LIFEPLUS AR Guide visual presentation.

4 Experiences Gained from LIFEPLUS application at Pompeii

The development of the LIFEPLUS prototype system faced many challenges both in the interpretation of the archaeological findings and in the technical solutions that were sought. The reader should not underestimate the innovative nature of the project and the cutting edge technologies developed and used (namely Augmented Reality). Their adaptation to the difficult operating conditions of crowded archaeological sites was a major challenge and one of the few such efforts worldwide.

The system had to provide real-time high-quality Augmented Reality presentations using nothing more than off-the-shelf notebook computers. Currently, the very high processing requirements of the user tracking, 3D modeling, and rendering of the augmented worlds necessitate the cascading of two processing devices, which have to be carried by the touring user. This set-up is far from optimal but enables the demonstration of the main principles conveyed by the system. It is now our aim to reengineer it and reduce its size and weight with the ultimate goal to offer the LIFEPLUS experience using lightweight wearable computers.

On the technical side, the development of the tracking module was a very difficult task. It combined three different technologies (GPS, digital compass, video tracking) under very difficult operating conditions. Similar technologies have been applied to other systems in stable (non-changing) indoor controlled environments where no interference was present and accurate 3D modeling of the application space was available. Also, its forerunner, the ARCHEOGUIDE system, makes use of similar technologies in uncontrolled outdoor archaeological sites with enough success. However, fairly relaxed accuracy constraints are used in ARCHEOGUIDE and the system offers audiovisual content only at predefined locations in the site.

In our application these assumptions fail to hold as LIFEPLUS is used both in outdoor and indoor archaeological sites. This means that the system's optical module (video tracking) must be able to adapt to very high variations of the lighting conditions as the user transits from sunny open areas to the interior of dark buildings. This also poses serious problems to the augmented reality visualization unit, a head-mounted display in the form of binoculars, which must be capable of offering high contrast photo-realistic computer-generated models rendered on top of the user's real view.

Dynamic adaptation to the user's profile, available time and behaviour is a new concept applied to LIFEPLUS for the personalization of the audio-visual content. This ensures the capture of the user's interest but at the same time demands efficient algorithms and sensory input to implement its dynamic nature in contrast to previous efforts by other systems.

Interactivity and manipulation of 3D data in real-time is another innovative feature supported by efficient multi-modal interaction techniques and fast graphics hardware.

Finally, a very interesting part of the system is its portability to any site and the ease of updating of the multimedia content and augmented reality tours it offers its users. This feature is achieved by its modular design, and the use of international standards.

5 Conclusions and Future Work

The system received a warm welcome at Pompeii were it was initially trialed and demonstrated to a limited number of site staff and technology experts. It currently undergoes further development and re-engineering and an improved version is expected to be demonstrated on site within 2004 with the participation of large groups of site visitors.

Our efforts concentrate in the use of compact and lighter equipment so as to make it easier to carry. Battery life is another concern and the use of a single power source is investigated for all the peripheral hardware with the aim to have autonomy of at least one hour for continuous operation.

Finally, content personalization is further investigated together with documentation. For this purpose the Dublin Core Element Set (http://www.dublincore.org [2003]) is been investigated and additional metadata descriptions are added to cover the needs of the system.

Following the completion of the project next year, it is expected to raise publicity and interest for commercial exploitation in cultural heritage sites and museums. The system itself is expected to become and attraction of its own and help increase the visibility of such sites.

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